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A new technique for spectroscopic resolution of optical atomic clock.	opy of atomic hydrog hydrogen-or any neut	gen has been o tral atomic spe	developed, opening the ecies, and perhaps ma	e way to a king poss	a thousand-fold increase ible a new type of UV
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## **FAX COVER SHEET**

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December 18, 1996

Dr. Ralph Kelley Air Force Office of Scientific Research Bolling Air Force Base, Building 410 Washington, DC 20332 Dear Dr. Kelley,

The is the Final Report for AFOSR Grant F49620-93-1-0215.

Under this grant we have developed a new technique for spectroscopy of atomic hydrogen which opens the way to a thousand-fold increase in spectroscopic resolution of hydrogen—or indeed any neutral atomic species—and may make possible a new type of optical atomic clock operating in the UV region.

We have succeeded in carrying out two-photon Doppler-free spectroscopy of atoms that are confined in a magnetic trap. The transition we observe, the  $1S \rightarrow 2S$  two-photon (243nm) transition, is to a metastable state with an extremely long lifetime, 1/8 sec. The trap is highly non-perturbative, permitting observation times limited ultimately by the natural lifetime, yielding a natural linewidth of about 1 Hz. In our initial experiments we achieved a resolution of about three kHZ, higher than the best then achieved by other techniques and apparently limited only by laser jitter, which we are now trying to improve. We have observed signal rates as high as 3000 counts per second. The collection efficiency in the initial version of our apparatus is less than  $10^{-5}$ , and so the actual signal rate is greater than  $10^8$  counts per second, which compared to previous methods, is almost astronomically high. In addition, we have directly measured the life time of the metastable 2S atoms, and have observed it to be close to the theoretical lifetime of 0.12 sec. This is the first time the 2S lifetime has been measured.

The performance of our system gives promise that a new type of optical clock, based on the  $1S \rightarrow 2S$  two-photon transition in hydrogen, may be feasible. We have started an analysis of this system with a view to creating such a clock. In addition, the spectroscopic techniques developed in this work provide a powerful tool for studying Bose-Einstein condensation in hydrogen, and the possible creation of a coherent atomic beam of hydrogen- a hydrogen atom laser.

## **PUBLICATIONS AND THESES**

Two-photon spectroscopy of trapped atomic hydrogen, Claudio L. Cesar, Dale G. Fried, Thomas C. Killian, Adam D. Polcyn, Jon C. Sandberg, Ite A. Yu, Thomas J. Greytak, Daniel Kleppner, and John Doyle, Phys. Rev. Lett. 77, 255 (1996)

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Doppler-Free Spectroscopy of Trapped Atomic Hydrogen, T.C. Killian, D.G. Fried, C.L. Cesar, A.D. Polcyn, T.J. Greytak and Daniel Kleppner, Proceedings of the Fifteenth International Conference of Atomic Physics, to be published

(In preparation) Two-photon Doppler-Free Spectroscopy of Trapped Atoms, Claudio L. Cesar and Daniel Kleppner

## **THESES**

Claudio L. Cesar, Ph.D. thesis Two-Photon Spectroscopy of Trapped Atomic Hydrogen, M.I.T., December 1995

Sincerely,

Daniel Kleppner

Lester Wolfe Professor of Physics

Da Kleppe